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SURFACE TREATMENT OF PLASTIC FILM BY USING AN ATMOSPHERIC PRESSURE CORONA TORCH

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Abstract: Using a simple DC discharge corona torch under atmospheric pressure has carried out surface treatments of the plastic film for improving hydrophilic property. Although the input power of the torch was very small only about 1~5W, it enables to decrease the contact angle of a ethylene glycol drop on the film surface from 50° to 5° within 1~2 minutes. The contact angle of the film after treatment recovered to approximately 20° in 5 days and then, kept almost unchanged thereafter. Data will be presented and discussed.

1. INTRODUCTION

Surface treatment of polymeric materials using discharge plasmas of the gases including oxygen or fluorine can improve the hydrophilic or hydrophobic properties of the materials have been reported in some low gas pressure discharges [1], [2]. These modifications of surface properties were explained by the formation of oxygen or fluorine functionalities on the material surface as the result of implantation of radicals existing in the discharge plasma.

For practical uses, however, surface modification is desirable to be done under atmospheric pressure to simplify the equipment and thus, various types of atmospheric pressure nonthermal plasma produced by pulsed or AC corona discharges for surface modification have been also reported [3], [4], [5].

In this paper, we report another experiment of surface treatment by using a simple DC type discharge corona torch at atmospheric pressure.

This small pen-like corona torch used is consisted of two coaxial cylindrical electrodes with different length and the plasma is produced by the surface discharge along the ceramic tube which is inserted between the two electrodes.

Although the input power of the torch is very small, a stationary plasma can be obtained under atmospheric pressure and it enables us to make a long time surface treatment of plastic film for improving the hydrophilic property. The time for treatment seems important with relation to the time of recovery of the hydrophilic property after treatment. All data will be presented and discussed.

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2. EXPERIMENTAL APPARATUS AND METHODS

As shown in Fig.1, the stainless steel made cylindrical tube of 6.5mm diameter and 170mm length was used as the inner electrode and a 15mm length stainless steel ring was located at the distance 15mm from the tip of inner electrode as the outer electrode. A ceramic tube of 12mm diameter and 150mm length was inserted coaxially between the two electrodes for insulation. Electrical discharge was made by applying high voltage between the electrodes using a DC power supply (CS9002-30A of ULTRAVOLT Inc) which could be varied from 0~30kV. The Ar+N_2 gas mixture was flow through the inner electrode tube for driving the discharge and a visible plasma of approximately 5~10mm long was formed downstream of the flow because of the ionization of driving gas by the discharge. The plastic film to be treated was put on a sample holder made of acrylic board placed downstream of the flow and the distance from the holder to the tip of inner electrode could be varied from 0~40mm.

The various particle species in the plasma were measured by the spectroscopic method and the variation of hydrophilic property was checked by measuring the contact angle using a contact angle meter.

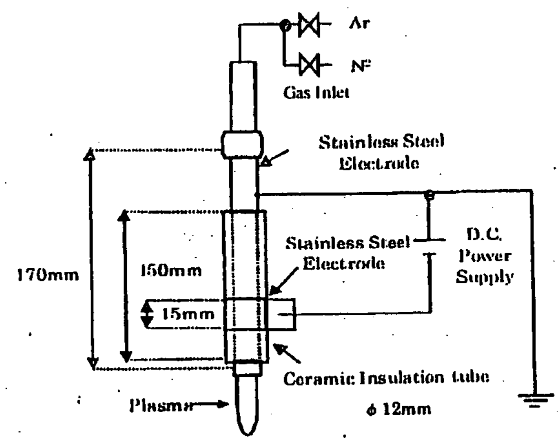

FIGURE 1 Schematic of atmospheric pressure corona torch

3. EXPERIMENTAL APPARATUS AND METHODS

Typical voltage-current characteristics of the discharges with varying $Ar+N_2$ gas mixture ratio are shown in Fig.2. Discharge begins approximately from the applied voltage of 10kV. The discharge current increases with increasing applied voltage and becomes approximately 250μA at the voltage of 20kV, thus it is estimated that the total input power is very small only about 1~5W.

Fig.3 shows typical spectra intensities of N_2 1st positive system bands (1PSB, 673.5nm), N_2 2nd positive system bands (2PSB, 380.5nm) and N_2^+ 1st negative system bands (1NSB, 434.5nm) with varying gas mixture ratio. As can be seen from the figure, emission from the N_2^+ 1st negative system bands is very weak because of the ionization rate is very low. All the spectra intensities are most enhanced for the gas mixture ratio of N_2 5% implies that under this condition, the highest density of N_2 radicals are existing in the discharge.

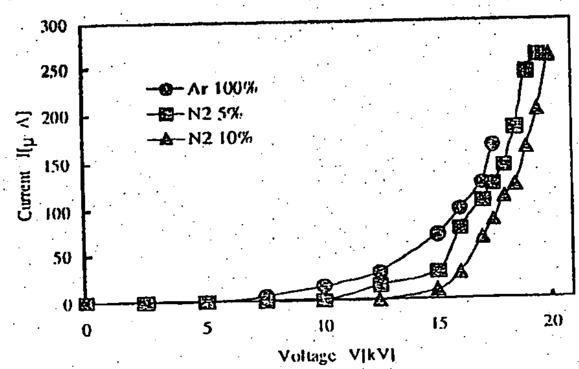

FIGURE 2 Corona torch V-I characteristics

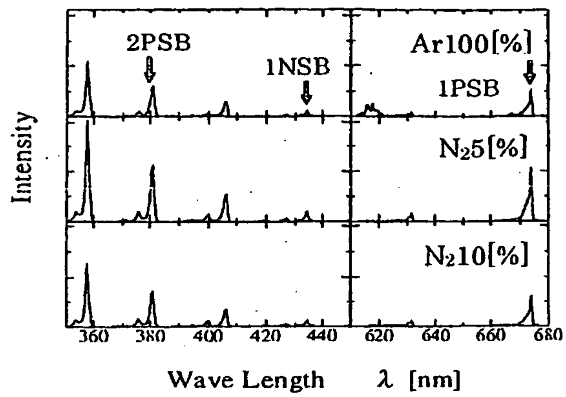

FIGURE 3 Corona torch V-I characteristics

Fig.4 shows typical results of the treatment of polyethylene terephthalate film (PET, 20×20×0.2mm) with varying the Ar+N_2 gas mixture ratio. Experiment was carried out under the conditions of discharge current 60μA, gas flow rate 15l/min. The sample was located 5mm below the tip of the inner electrode. Since the hydrophilic property can be expressed by contact angle, the relations between the measured contact angle using a ethylene glycol drop with the treatment time. As can be seen from the figure, the measured contact angle decreases sharply with increasing treatment time within 1~2 minutes and after this, becomes almost a constant value. Also, the treatment was most effective under the condition of 5% nitrogen gas mixture ratio in coincidence with the result of optical spectra intensity measurement as shown in Fig.3. This result implies that the excited high energy radicals existing in the plasma may play an important role for improving the hydrophilic property by enhancing the formation of oxygen functionalities on the film surface.

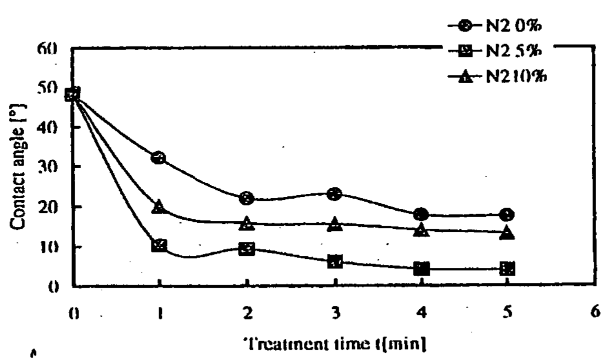

FIGURE 4 Effect of plasma treatment time on contact angle

Since the hydrophilic property of the film is related to the surface free energy which is composed of the intermolecular forces of dispersion force, dipole force and hydrogen bond force, each ingredient forces as well as the surface free energy were also measured. Typical results for the case of 5% N_2 gas mixture ratio are shown in Fig.5. As can be seen from the figure, surface free energy increases by the treatment, that is, the hydrophilic property is improved. However, as to the after forces, only the hydrogen bond force increases with increasing treatment time same as the behavior of surface free energy. These results support that, the improvement of hydrophilic property may be caused by the formation of hydroxyl group functionalities on the film surface.

Fig.6 shows typical recovery characteristics of the film using the sample treated 3 minutes in 5%

nitrogen gas mixture ratio discharge. The treated film was exposed to the air and the contact angle was measured once a day at every day's evening. As can be seen from the figure, the contact angle recovers from 5° to 20° within 5 days but after 5days, remains almost unchanged. The long durability of the hydrophilic property may be caused by the formation of sufficient thick layer of hydroxyl group functionalities on the film surface as the result of a rather long time treatment in a small input power discharge.

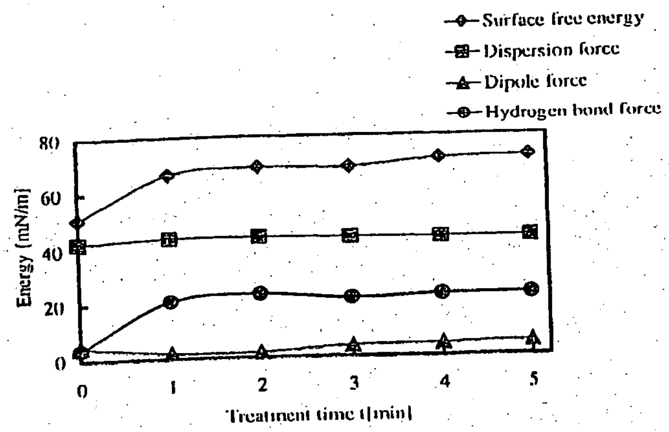

FIGURE 5 Surface free energy characteristics

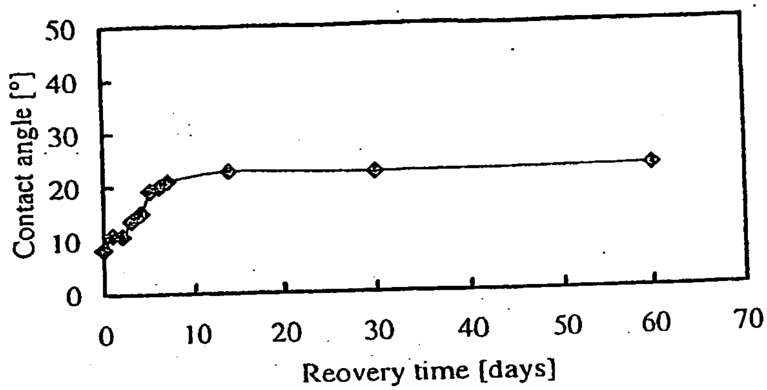

FIGURE 6 Durability test

4. SUMMARY

A simple DC discharge type atmospheric pressure corona torch with small input power of 1~5W has been developed and applied to the surface treatment of PET film for improving the hydrophilic property. Experimental results show that :

(1) The contact angle decreases within 1~2 minute treatment from 50° to below 10° for the case of 5% N_2 gas mixture ratio which is the most effective gas mixture ratio for surface treatment.

(2) The contact angle recovers from 5° to 20° within 5 days after treatment and remains almost a constant at about 20° thereafter.

(3) The measured spectra intensities and hydrogen bond force indicate the possibility of the formation

of hydroxyl group functionalities on the film surface for improving the hydrophilic property.

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